

## German Final Devoicing in Optimality Theory

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## **German Final Devoicing in Optimality Theory\***

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### **0 Introduction**

German has a famous alternation called Final Devoicing, by which some underlyingly-voiced consonants become voiceless, as has been noted by many researchers (cf. Wurzel (1970), Vennemann (1972), Kloeke (1982), etc.). There is, however, a considerable number of words which do not undergo the alternation even when the environment is met, as we will review in the next section. To solve this problem, Rubach (1990) proposed that syllabification occurs cyclically in German. In this paper, I will suggest that his analysis is problematic in several respects, and that this phenomenon is best analyzed in the framework of Optimality Theory (cf. Prince and Smolensky (1993)).

### **1 Final Devoicing**

First, let us review Final Devoicing. Observe the alternation of the underlined consonants in (1): a stem-final voiced obstruent in (1a) alternates with its voiceless counterpart in (1b).

(1)	a.	Tag-e	[g]	'days'	b.	Tag	[k]	'day'
		kind-isch	[d]	'childish'		Kind	[t]	'child'
		Auslän <u>d</u> -er	[d]	'foreigner'		Auslän <u>d</u>	[t]	'foreign country'
		Häus-er	[z]	'houses'		Haus	[s]	'house'
		Smaragd- <u>e</u>	[kd]	'emeralds'		Smaragd	[kt]	'emerald'
		Jag- <u>d</u> -en	[kd]	'hunting'(pl.)		Jag- <u>d</u>	[kt]	'hunting'

(Rubach (1990))

As the name indicates, this alternation is analyzed as *devoicing* of the obstruents in (1a), but not as *voicing* of the ones in (1b). Note that underlyingly voiceless obstruents are not voiced when a vowel-initial suffix follows it. Compare *Welt* 'world'/'*Welten* 'world (pl.)' with *Jagd*/'*Jagden*: when the plural suffix *-en* follows, the stem-final consonant of *Jagden* is voiced while that of *Welten* is voiceless, although they are both voiceless without the suffix. This difference suggests that the stem-final consonant of *Jagd-en* is underlyingly voiced and gets devoiced in *Jagd*, while that of *Welt-en* is underlyingly voiceless.

Following Vennemann (1972), Rubach (1990) concludes that Final Devoicing applies to

the obstruents which lie in the syllable coda: in coda position the relevant consonant is voiceless (1b), while it is voiced when it appears as the onset (1a). In other words, Rubach denies the analysis in which it is assumed that Final Devoicing applies to the obstruents which are morpheme-final (cf. Wurzel (1970), Kloeke (1982)). Rubach's analysis is adequate particularly when we consider the [d] in *Jagden*; if morpheme-final obstruents were to be devoiced, the word would be pronounced as \*[jakten] since the morpheme-boundary lies between the [d] and the suffix *-en*. Moreover, Rubach gives the following examples.

- (2) Admiral [t] 'admiral', administrativ [t] 'administrative', Obduction [p] 'obduction',  
Edmund [t], Edna [t], Edger [t] (Rubach (1990))

The words in (2) are all loan words, and thus presumed to be monomorphemic to native German speakers. The underlined consonants get devoiced in German, although the original words have voiced consonants as the spelling indicates. Because these words undergo Final Devoicing, we should conclude that the rule applies to coda obstruents, not to the morpheme-final ones.

However, the words in (3a) do not conform to the generalization we have made above; that is, coda obstruents devoice. The underlined consonants are voiced even when they lie in coda position.

- |     |    |                    |     |           |    |                    |     |                 |
|-----|----|--------------------|-----|-----------|----|--------------------|-----|-----------------|
| (3) | a. | Hand <u>u</u> ng   | [d] | 'act'     | b. | hand <u>l</u> ich  | [t] | 'handy'         |
|     |    | Ord <u>n</u> ung   | [d] | 'order'   |    | Bil <u>d</u> nis   | [t] | 'portrait'      |
|     |    | eb <u>n</u> en     | [b] | 'flatten' |    | Ergeb <u>n</u> is  | [p] | 'result'        |
|     |    | Begeg <u>n</u> ung | [g] | 'meeting' |    | Wagn <u>i</u> s    | [k] | 'boldness'      |
|     |    | eig <u>n</u> en    | [g] | 'own'     |    | Zeugn <u>i</u> s   | [k] | 'testimony'     |
|     |    | neb <u>l</u> ig    | [b] | 'foggy'   |    | glau <u>b</u> lich | [p] | 'believable'    |
|     |    |                    |     |           |    |                    |     | (Rubach (1990)) |

Moreover, there are words which do undergo Final Devoicing (3b), although the consonant in question appears in the same sequence as (3a). For example, /d/ retains its voicedness in *Handlung*, in the /ndl/ sequence, while it gets devoiced in *handlich* although it lies in the same sequence /ndl/.

The number of the words which belong to (3a) is too large to regard them simply as "exceptions". This fact leads us to cast doubt upon the validity of Rubach's analysis, which postulates the devoicing of coda obstruents. In the next section, we will review two analyses which try to solve this problem preserving Rubach's analysis of coda devoicing.

## 2 Previous Analyses

### 2.1 Rubach (1990)

To solve the problem we have seen in the previous section, Rubach first observes the difference of the morphological structure of the words in (3). As (4b) shows, the words in (3b) have morphological boundary just after the consonant in question, while those in (3a) do not (4a).

- |     |    |                            |    |            |
|-----|----|----------------------------|----|------------|
| (4) | a. | Handl+ung (cf. handel-n)   | b. | hand+lich  |
|     |    | Ordn+ung (cf. ordn-en)     |    | Bild+nis   |
|     |    | ebn+en (cf. eben)          |    | Ergeb+nis  |
|     |    | Begegn+ung (cf. begegn-en) |    | Wag+nis    |
|     |    | eign+en (cf. eigen)        |    | Zeug+nis   |
|     |    | nebl+ig (cf. Nebel)        |    | glaub+lich |

Interestingly, the morpheme-final consonants whose preceding obstruents do not undergo Final Devoicing are all sonorants, as we see in (4a). From this fact, Rubach assumes that the relevant obstruents in the words in (3a) are syllabified as the syllable onset, with the following sonorants syllabified as the nucleus within the same morpheme. Since the obstruents in question are the onset, they do not undergo Final Devoicing.

To guarantee this syllabification, Rubach employs a special mechanism of cyclic syllabification for German. Syllabifying cyclically gives a chance for the sonorants in the words in (3a) to become the nucleus, but not for those in the words in (3b) since they are available only after the suffix is attached. Rubach proposes the rule in (5), which renders the sonorants nuclei.

#### (5) Sonorant Syllabification

$$\begin{array}{ccc}
 & & \sigma \\
 & & | \\
 *C & \rightarrow & C \\
 [+ \text{son}] & & 
 \end{array}$$

The asterisk indicates that the consonant is not syllabified. When a sonorant is left unsyllabified in accordance with the Sonority Sequencing Principle (cf. Steriade (1982), etc.) in the cycle of stem, the rule in (5) syllabifies it as the syllable nucleus.

Let us see how Rubach's assumption of cyclic syllabification solves the problem of Final Devoicing. In (6) I give derivations of *Handlung*, *handlich* and *kindisch*.

(6)	Handlung	handlich	kindisch	
<i>Cycle 1</i>				
	$\sigma$ /l\	$\sigma$ /l\	$\sigma$ /l\	Syllabification
	hand<l>	hand	kind	
	$\sigma \sigma$ /l\ l	-----	-----	Sonorant Syllabification
	handl			
	$\sigma \sigma$ /l\ \	-----	-----	Syllabification
	handl			
<i>Cycle 2</i>				
	$\sigma \sigma$ /l\ \	$\sigma$ /l\	$\sigma$ /l\	Suffixation
	handl + ung	hand + lich	kind + isch	
	$\sigma \sigma \sigma$ /l\ \ /l\	$\sigma \sigma$ /l\ \ /l\	$\sigma \sigma$ /l\ /l\	Syllabification
	handl ung	hand lich	kindif	
<i>Postcyclic</i>				
	-----	[t]	-----	Final Devoicing
	$\sigma \sigma$ /l\ /l\	-----	-----	Sonorant Desyllabification
	handl ung			
	$\sigma \sigma$ /l\ \ /l\	-----	-----	Syllabification
	handlung			

In the first cycle of *Handlung*, the stem-final /l/ of /handl/ is left unsyllabified because of the Sonority Sequencing Principle. It is syllabified as the syllable onset by Sonorant Syllabification (5), and the preceding consonant is resyllabified as the onset of the newly-assigned syllable. In the second cycle, where suffixes are attached to the stem, syllabification applies again, respecting the syllable structure produced in the previous cycle. At the post-cyclic level, where Final Devoicing applies, the /d/ in *Handlung* escapes from undergoing the rule since it is syllabified as the onset, while that of *handlich* undergoes the rule.

Besides Final Devoicing, Rubach postulates a rule called Sonorant Desyllabification, which deprives syllabic sonorants of their syllabicity. This rule is necessary for accounting for epenthetic schwas, which Rubach assumes to appear before syllabic sonorants. Note that when the stem /handl/ appears without any suffix, it has an epenthetic schwa, which is described with the letter *e* in German, before the syllabic /l/: e.g. *Handel* 'trade (N.)'. On the other hand, such a vowel does not emerge in *Handlung*. It follows from this fact that the /l/ in *Handlung* is not syllabic in the surface form, while it is in *Handel*. Sonorant Desyllabification accounts for this difference in syllabicity; the /l/ in *Handlung* loses its syllabicity because of this rule, and it is resyllabified as the onset at the end of the derivation.

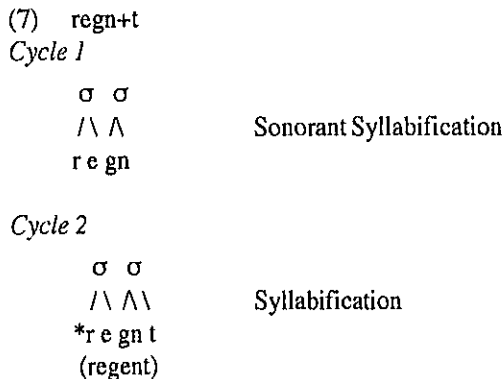
Rubach's analysis, however, has several problems. First, it seems that Sonorant Syllabification and Sonorant Desyllabification, which serve for the opposite purposes, are posited only to prevent Final Devoicing from applying to the words in (3a). The /l/ in *Handlung* once becomes syllabic by Sonorant Syllabification, and again gets unsyllabic through Sonorant Desyllabification after the word passed through the stage in derivation at which Final Devoicing applies. This set up of the rules seems very arbitrary.

Second, it is not clear why syllabic sonorants are not resyllabified into the following syllable at the second cycle. Note in (6) that the stem-final /d/ of /kind/ is syllabified as the coda at the first cycle, and resyllabified as the onset at the second cycle. This resyllabification is necessary, otherwise the /d/ of *kindisch* would undergo Final Devoicing as *Kind* does. On the other hand, the stem-final /l/ of *Handlung* is never resyllabified into the following syllable before the application of Final Devoicing, even though the following syllable is onsetless. Why does such a difference arise? One may say that once a syllable is produced it must not be eliminated. But such an explanation is not satisfactory, since even in the syllabification in which the /l/ is resyllabified as the onset the syllable is retained as the second syllable of *.hand.lung.*, where the vowel of the suffix becomes the nucleus of the syllable (that is, there is no necessity to produce a new syllable when a suffix is attached). Another possibility is that the /l/ retains the role of syllable nucleus, but such an account also is unnatural because it is not a feature or an autosegment assigned to a segment that determines the nucleus of a syllable.

The third problem is that a cycle which does not correspond to a distinct word must be posited for some words. For example, to account for the voicedness of /g/ in *Begegnung* the cycle *\*begeg(e)n* must be posited, but such a word does not serve as a distinct word. Similarly, although German lexicon contains *Orden* 'medal', it is difficult to assume that this

word is the stem of *Ordnung* 'order' since they are so different in meaning.

Finally, it is impossible to predict correct syllabification of the word *regnet* 'rain (3rd. sing.)'. This word consists of the stem /regn/ (cf. *regn-en* 'rain (3rd. pl.)') and the inflectional suffix /t/. In Rubach's analysis, the word would undergo the following derivation.



In the first cycle, the second syllable /gn/ is produced by Sonorant Syllabification (and actually the stem appears as a noun *Regen*, in which the epenthetic schwa emerges in front of the syllabic /n/). The suffix /t/ is syllabified as the coda of this syllable in the second cycle, because the sequence of syllabic nasal plus /t/ is legal in German (cf. *Abend* 'night'). The form *\*regent* is predicted, which is not true: the actual form is *regnet*. The only possible way to produce the actual form in Rubach's analysis is to assume that the suffix contains the schwa underlyingly (i.e. /et/), but this is also impossible since such a schwa does not appear in other forms (e.g. *bau-t*/\**bau-et* 'build (3rd.sing.)').

## 2.2 Zamma (1995), Lombardi (1995)

Observing the problems in Rubach's analysis presented above, Zamma (1995) presented another analysis which postulates that a schwa is present underlyingly after the underlined consonants in (3a), and that it is deleted after Final Devoicing. In other words, the consonants in question lie in onset position underlyingly rather than in coda, and thus are immune from Final Devoicing (Lombardi (1995) also presents the same kind of analysis). For example, *Handlung* is derived from underlying /handel/ + /ung/ and the schwa after /d/ is deleted through the following rule:

### (8) Schwa Deletion<sup>1</sup>

A schwa is deleted when it lies in the following environment: e [+son] e(i, u).

(8) being ordered after Final Devoicing, the voicedness of the /d/ in *Handlung* is preserved

through the rule.

(9)	Handel + ung	hand + lich	
	-----	[t]	Final Devoicing
	Handlung	-----	Schwa Deletion

The obstruents that undergo Final Devoicing do not contain such an underlying schwa, as the derivation of *handlich* shows. Whether the underlying form contains a schwa or not becomes clear when we observe other forms of the word. The stem /handel/ has forms such as *Handel* and *handelt* 'trade (3rd.sg.pres.)', while the stem /hand/ does not have such forms.<sup>2</sup>

Most of the cases immune from Final Devoicing, as well as the distribution of German schwa, can be accounted for in this analysis, as I have argued in Zamma (1995). However, one crucial problem arises in this analysis; that is, this analysis too cannot predict the form *regnet* for /regn/ + /t/.

(10)	Regen + t	Suffixation
	-----	Final Devoicing
	-----	Schwa Deletion
	*regent	

From the facts that the /g/ in the stem does not undergo Final Devoicing and that there is a form *Regen* 'rain (N.)', it is assumed in this analysis that the stem contains a schwa underlyingly. With this assumption, however, the wrong form \**regent* is predicted, in which the suffix -t is attached directly to the stem. Recall that such a syllabification is quite natural in German as we have seen in the previous section.

On the other hand, assuming that the suffix itself contains a schwa and the schwa in the stem is deleted by (8) (i.e. /regen-et/ → /regn-et/) is also problematic. First, if the suffix schwa is deleted by the rule, why does the same deletion rule not apply to *handel + et*, in which the suffix schwa, not the one in the stem, deletes (note that the actual form is *handelt*, not \**handlet*)? Second, a special deletion rule must be posited to account for the form *baut* 'build (3rd. sg.)' from *bau + et*. From these facts we conclude that the inflectional suffix is -t, that is, without a schwa. In this case, it is impossible to predict the form *regnet* in this analysis, as we have seen in the derivation in (10).



### 3 Alternative Approach

#### 3.1 Sonorant Licensing

Because previous analyses are both problematic in several respects, we have to pursue another approach. First, we consider the possibility that German has the following rule:

(11) Pre-Sonorant Voicing

[+obs] → [+voi] / \_\_ [+son] #

We have observed in (4) that the consonants immune from Final Devoicing precede a sonorant and a morpheme boundary. If the rule in (11) is ordered after Final Devoicing, the voicedness of the /d/ in *Handlung* is explained in the following derivation:

(12) Handl + ung

Han[t]lung                      Final Devoicing

Han[d]lung                      Pre-Sonorant Voicing

Although the /d/ undergoes Final Devoicing, it is voiced again because of Pre-Sonorant Voicing.

This approach, however, also raises a problem. Positing the rule Pre-Sonorant Voicing is so powerful that it is predicted that the rule would apply to many words which never undergo the rule. Consider the derivation of *atmen* 'breathe (1st.pl.)'.

(13) atm + en

-----                      Final Devoicing

\*a[d]men                      Pre-Sonorant Voicing

The /t/ in front of /m/ would be voiced by Pre-Sonorant Voicing. The actual form is, of course, *a[t]men*.

Because positing a rule like (11) is too strong, we reconstruct the idea that a following isomorphic sonorant relieves a consonant from undergoing Final Devoicing into a looser mechanism. That is, we postulate a device which makes only underlyingly voiced obstruents retain its voicedness through Final Devoicing. Note that the defect in (11) is that the rule voices any obstruents in front of a sonorant, whether they are underlyingly voiced or not. What we need here is a apparatus which guarantees the voicedness of underlyingly voiced segments. The following condition, called Sonorant Licensing here, serves the purpose.

(14) Sonorant Licensing:    An isomorphic sonorant licenses [+voice] of the preceding segment.

Of course, obstruents which are underlyingly voiceless do not become voiced by means of

(14).

Positing such a licensing condition as in (14) leads us to translate Final Devoicing into a constraint as in (15).

(15) Coda Constraint: Coda obstruents do not license [+voice].

Note that (14) suggests there is a case in which the feature [+voice] is not licensed. Devoicing occurs in such a case. In particular, the underlined consonants in (1b) do not license [+voice] in accordance with (15), and thus devoice. In other words, devoicing takes place by delinking the feature [+voice] as a repair strategy (Lombardi (1995) also considers Final Devoicing in this way).

Now the difference in voicedness of the /d/ in *Handlung* and *handlich* is easily accounted for. In the former, the voicedness is licensed by the isomorphemic // because of (14), therefore the [+voice] of the /d/ is not delinked. Such is not the case for the latter since the // is heteromorphemic, and thus the preceding segment is deprived of its voicedness to observe the Coda Constraint (15).

We should note here that (14) prevents some obstruents to become voiceless because of (15) in this analysis. This means that there is an interrelation between the two constraints, (14) and (15), and that it is this interrelation that determines whether an obstruent undergoes Final Devoicing or not. Stating such a relation among constraints in the traditional framework tends to be vague, but the relation is easily captured in Optimality Theory (henceforth OT), since it is one of the basic ideas of the theory that there is a correlation among constraints. We propose that German Final Devoicing is best analyzed in the framework of OT, and we will give more detailed analysis of Final Devoicing based on OT in what follows. Before presenting such an analysis, we will briefly review OT in the next subsection.

### 3.2 Optimality Theory

OT is a theory which admits neither rules nor derivations and assumes that output forms are determined in the interaction of constraints. In OT, grammar is considered to be organized in the following way:

- (16) a.  $\text{Gen}(\text{In}_k) \rightarrow \{\text{Out}_1, \text{Out}_2, \dots\}$   
 b.  $\text{H-eval}(\text{Out}_i, 1 \leq i \leq \infty) \rightarrow \text{Out}_{\text{real}}$

For an input, Gen(erator) can produce any output (16a). Among the unlimited set of the candidates, H(armonic)-eval(uation) determines the real output. H-eval consists of numerous

constraints, and the evaluation is carried out in the following way. Suppose there are three constraints A, B and C, and they are ranked as in (17).

(17) constraint A » constraint B » constraint C

This constraint hierarchy suggests that constraint A is the most important and C is the least. When Gen produces three candidates and each of them violates some of the constraints, the real output is determined in the way as (18) shows.

(18)

	constraint A	constraint B	constraint C
candidate 1	*!		
⇒ candidate 2		*	*
candidate 3		**!	

Candidate 1 violates the most important constraint A, and thus loses ("!" means that this is the fatal violation. The columns right to the fatal violation are irrelevant and thus shaded). As for constraint B, candidate 2 violates it once and candidate 2 twice. The second violation of candidate 3 is fatal, and candidate 2 wins as the arrow indicates. Although candidate 2 violates constraint C, this violation is less important than the second violation of constraint B of candidate 3, and thus regarded as irrelevant.

### 3.3 Final Devoicing in Optimality Theory

Now let us see how the issue we are considering is accounted for in this theory. First, we reinterpret Final Devoicing as the following constraint, as we have seen in section 3.1.

(19) **Coda Constraint:** Coda obstruents do not license [+voice].

Because of this constraint, the voicedness of the /d/ in *handlich* is deprived. Note that the words which undergo Final Devoicing (via (19)) violate the following constraint.

(20) **Parse-[v]:** [+voice] in the input must be parsed into the output.

This constraint requires the output to be identical with the input as to voicedness. Those outputs that undergo devoicing violate this constraint, since the voicedness which the input has is lost in such outputs. Because a great number of words undergoes Final Devoicing, it is clear that (19) is ranked in a higher position than (20) in German.

Second, following Itô, Mester and Padgett (1995), we assume that the [+voice] of the consonant in the left in (21) can be licensed by the consonant in the right, even if the consonant in the left is an obstruent which lies in syllable coda.

- (21) C C  
 \ /  
 [+voice]

Noting that the voicedness of a coda obstruent is only admitted to the ones which is followed by an isomorphic sonorant, we postulate a constraint which reflects this restriction. The constraint is (14), reproduced here as (22).<sup>3</sup>

- (22) **Sonorant Licensing:** An isomorphic sonorant licenses [+voice] of the preceding segment.

This constraint prohibits a feature from being licensed by a heteromorphic sonorant. In other words, the structure in (23) violates (22) ("|" stands for a morphological boundary).

- (23) C | C  
 \ /  
 [+voice]

Among the three constraints we have presented, we assume that there is a ranking as shown in (24).

- (24) **Coda Constraint, Sonorant Licensing » Parse-[v]**

With this constraint hierarchy, we can account for German Final Devoicing in OT. Recall that *handlich* and *Handlung* contrasts in whether the word undergoes Final Devoicing or not. First, observe the tableau in (25).

(25)

	CodaCon	SonLic	Parse-[v]
han[d]lich   [+voice]	*!		
han[d]llich \ / [+voice]		*!	
⇒ han[t]lich			*

The first candidate violates **Coda Constraint**, since the /d/ in coda licenses [+voice] by itself. Although the [+voice] is licensed by the following /l/ in the second candidate, it violates **Sonorant Licensing** since the /l/ is heteromorphic. The third candidate is selected as the optimal output: although this candidate violates **Parse-[v]** not parsing [+voice], this violation is less serious than those of two other constraints. The ranking in (24) correctly predicts that

Final Devoicing applies to *handlich*. In other words, the /d/ in *handlich* is devoiced in order to satisfy the two constraints **Coda Constraint** and **Sonorant Licensing**.

On the other hand, Final Devoicing does not apply to *Handlung*. The ranking in (24) accounts for this fact as we see in the following tableau.

(26)

	CodaCon	SonLic	Parse-[v]
<sup>a</sup> han[d]lung   [+voice]	*!		
⇒ han[d] l lung \ / [+voice]			
han[t]lich			*!

The /d/ in coda having [+voice] by itself, the first candidate violates **Coda Constraint** and thus loses. The third candidate satisfies **Coda Constraint** and **Sonorant Licensing**, but it violates **Parse-[v]** by delinking [+voice] of the coda obstruent. The second candidate is selected as optimal, because all of the constraints, including **Parse-[v]**, are satisfied: the isomorphemic /l/ licenses the [+voice] of the preceding /d/ and thus **Sonorant Licensing** is not violated. Consequently, the /d/ in *Handlung* does not devoice.

One may think that since Gen can produce any candidate, it is possible that candidates in which relevant consonants are syllabified as the onset rather than the coda are produced to satisfy **Coda Constraint**. These candidates, however, are problematic in several respects and thus are excluded from the consideration. Possible syllabification would be as follows:

- (27) a. Han.dl.ung  
       b. Han.dlung  
       c. Handl.ung

In (27a), /l/ is syllabified as the nucleus as is in Rubach's analysis. If *Handlung* is syllabified in this way, why does a schwa not appear between /d/ and /l/? Note that in German a schwa is inserted before a syllabic sonorant as in *Han.del*. (</handl/) and *Re.gen*. (</regn/) (cf. section 4). It is impossible to posit a constraint which prohibits the schwa insertion in *Handlung*, but requires such an insertion in *Handel*. The second possibility is that /d/ is syllabified in the second syllable as the onset (27b). If this syllabification were possible, the same would be

possible for *handlich* and the /d/ in this word would also retain its voicedness (note that both *Han.dlung* and *han.dlich* do not show alignment of the morpheme boundary and the syllable boundary (cf. McCarthy and Prince (1993))). Finally, syllabifying both /d/ and /l/ as the coda (to align the morphological boundary with the syllable boundary) would also raise a problem. It becomes necessary to revise Final Devoicing as applying only to the syllable final consonant, but not to the penultimate one. If syllabification is carried out in this way, that is, to align the morphological boundary with the syllable boundary, why does the /g/ in *Tag-e* not devoice because of the revised Final Devoicing? Since all of the possible syllabification analyses are problematic, we conclude that the analysis we have seen above is the most adequate in the framework of OT.

#### 4 Comparison: German Schwa

As we have seen in the previous section, OT analysis succeeds in analyzing German Final Devoicing properly: as well as the analysis accounts for the words which undergo Final Devoicing, it also explains why some words are immune from Final Devoicing. When we take into consideration the issue of German schwa, it becomes more evident that OT analysis is more appropriate than the traditional rule-based analysis. At the end of discussion, we will make a comparison between the two analyses by considering German schwa briefly. (A detailed analysis of German schwa in OT framework is to be presented in Zamma (to appear).)

##### 4.1 Rule-Based Theory

In German, a schwa is inserted when syllabification cannot be carried out properly otherwise. Clear examples of this schwa epenthesis are observed in suffixation of *-t*, as shown in (28).

(28) 3rd.sg./2nd.pl.

a.	<i>mach-t</i>		'make'
	<i>lieb-t</i>		'live'
	<i>bau-t</i>		
b.	<i>bad-et</i>	* <i>badt</i>	'bathe'
	<i>wart-et</i>	* <i>wartt</i>	'wait'

As the words in (28) show, the inflectional suffix for third person singular and second person plural is *-t*: if the suffix contains a schwa underlyingly, i.e. *-et*, there is no reason why the schwa is deleted in the words in (28a) (note that an underlying schwa in the suffix usually

surfaces as in *bau-en*). When the direct attachment of the suffix to the stem creates an illegal syllable, a schwa is inserted before the suffix as we see in (28b). Such an epenthesis rule can be formulated in the way as shown in (29).

(29) Schwa Epenthesis 1

$$\emptyset \rightarrow e / (C^*) \_ C^* \quad (C^* = \text{unsyllabified consonant})$$

(29) also applies when the stem-final consonant is nasal, as the examples in (30a) show. The derivation is shown in (31a). When the stem-final consonant is liquid, however, the epenthetic schwa appears before the stem-final consonant, not before the suffix (30b). This fact cannot be accounted for by the rule in (29), as (31b) shows.

(30) 3rd.sg./2nd.pl.

- a. regn-et  
atm-et
- b. hunger-t 'hunger (v.)' (< hungr + t (cf. hungr-e (1st.sg.), hungr-ig 'hungry'))  
handel-t 'trade (v.)' (< handl + t (cf. handl-e (1st.sg.), Handl-ung))

(31) a. .reg.nt → .reg.net.

- b. .hand.lt → \*.hand.let.

To account for the fact, another rule of schwa epenthesis is necessary. The rule would be formulated in the following way:

(32) Schwa Epenthesis 2

$$\emptyset \rightarrow e / \_ C_1^* C_2^* \quad (\text{where } C_1 \text{ is a liquid})$$

Moreover, it turns out that the fact is more complicated when we consider the schwa which appears between the stem and the inflectional suffix for first person singular and third person plural. For most of the cases, a schwa appears before the suffix consonant through (29), as the words in (33a) show. Those stems which end with a liquid undergo the rule in (32) and a schwa appears before the stem-final consonant (33b). Interestingly, also in cases where the stem ends with a vowel, a schwa is inserted before the suffix (33c).

(33) infinitive, 1st plural, 3rd plural

- a. mach-en 'make'
- sag-en 'say'

- b.    regel-n            'rule (v.)'  
       hunger-n        'hunger (v.)'  
 c.    bau-en            'build'  
       schnei-en        'snow (v.)'

Note that the sequence of a diphthong plus a nasal is entirely legal in German; e.g. *Zaun* 'town', *klein* 'small'. This fact suggests that the schwa epenthesis applies only in suffixation. Moreover, the epenthesis is restricted to occurring in the suffixation of *-n*. When *-t* is attached to the same stems as in (33c), the epenthetic schwa never appears; e.g. *bau-t*, *schnei-t*. Observing these facts, we assume a special rule of schwa epenthesis as in (34).

(34) Schwa Epenthesis 3

$$\emptyset \rightarrow e \quad / \quad V \# \_\_ n$$

Alternatively, it seems to be possible to assume that the suffix is *-en* rather than *-n*, in which case the rule in (34) can be dispensed with. Also in this analysis, however, a special of schwa deletion must be posited to account for the words in (33b), which is ordered before the epenthesis rule in (32). The derivation would be as follows: /regl/ + /en/ > /regln/ > /regeln/.

In any case, three rules are necessary for German in rule-based analysis to account for the facts presented here. For a restricted class of words the rules in (32) and (34) (or the alternative deletion rule) apply, while (29) applies for others (as an elsewhere case).

#### 4.2 Optimality Theory

On the other hand, German schwa epenthesis is treated in OT in the following way. First, the constraints in (35) are posited.

- (35) a.    **\*Ons/Nasal:**    A nasal consonant does not become the syllable onset.  
       b.    **\*Cod/Nasal:**    A nasal consonant does not become the syllable coda.  
       c.    **\*Ons/Liquid:**    A liquid consonant does not become the syllable onset.  
       d.    **\*Cod/Liquid:**    A liquid consonant does not become the syllable coda.  
       e.    **H-syl:**            Syllabification applies harmonically.  
       f.    **Fill-V:**            Vowels in the output must be in the input.  
       g.    **Parse-V:**        Vowels in the input must be in the output.

The ranking between (35a) and (35c), on the one hand, and (35b) and (35d), on the other, determines which a nasal/liquid prefers to be, the onset or the coda.<sup>4</sup> If **\*Ons/α** is ranked higher than **\*Cod/α**, the segment α is more likely to be the coda, and if the ranking is



reversed, it prefers to be the onset. **H-syl** is a set of syllabification constraints other than (35a) through (35d). A constraint such that requires a syllable to have a vowel would be included, but we do not discuss in detail because it is irrelevant here. (35f) and (35g) are popular faithfulness constraints, which demand identity between the input and the output. We assume that these constraints are ranked in the following way.

- (36) a. **H-syl, \*Cod/Nasal » \*Ons/Nasal, Fill-V, Parse-V**  
 b. **H-syl, \*Ons/Liquid » \*Cod/Liquid, Fill-V, Parse-V**

The ranking between **H-syl** and **\*Cod/Nasal/\*Ons/Liquid**, and among **\*Ons/Nasal/\*Cod/Liquid, Parse-V** and **Fill-V** is not determined.<sup>5</sup> Moreover, we just present distinct ranking for nasals (36a) and for liquids (36b) for the lack of evidence which suggests the ranking between **\*Ons/Nasal** and **\*Ons/Liquid**, and between **\*Cod/Nasal** and **\*Cod/Liquid**. What is important in (36) is that nasals are more likely to be the onset, while liquids prefers to be the coda.

With the ranking in (36), we can account for the difference of the place of the schwa between (30a) and (30b). Compare the table in (37) with the one in (38) (a period stands for a syllable boundary).

(37)

/atm/ + /t/	H-syl	*Cod/Nasal	*Ons/Nasal	Fill-V	Parse-V
.at.mt.	*!				
.a.temt.		*!		*	
⇒ .at.met.			*	*	

(38)

/hand/ + /t/	H-syl	*Ons/Liquid	*Cod/Liquid	Fill-V	Parse-V
.hand.lt.	*!				
⇒ .han.delt.			*	*	
.han.dlet.		*!		*	

In both cases, candidates without an epenthetic schwa violate **H-syl** and thus lose (the first row). In (37), the candidate with a schwa after /m/ wins over the one with a schwa before /m/, since nasals prefer to be the onset rather than the coda. On the other hand, a liquid preferring the coda to the onset, the candidate in the middle is selected as optimal in (38).

As for words whose stem-final segment is not a nasal or a liquid, the competition would be as follows:

(39)

/bau/ + /t/	H-syl	Fill-V	Parse-V
⇒ .baut.			
.bau.et.		*!	

Since the constraints **\*Ons/α** and **\*Cod/α** are irrelevant in this case, they are excluded from the tableau. Inserting a schwa violates **Fill-V**, and thus the candidate without epenthesis wins.

Next we will consider the fact observed in (33), that is, the fact observed in the suffixation of the inflectional suffix for first person singular and third person plural. We introduce another constraint in (40), which is posited in German by Mester (1995).

(40) **Align-R**: Align (MWd, R, PrWd, R) (cf. Mester (1995))

This constraint requires that the right edge of a morphological word should also be the right edge prosodically. In other words, it prohibits an epenthetic schwa to appear word-finally. As Mester (1995) argues, this constraint accounts for the schwa epenthesis in (41).

(41) /atm/      Atem      \*Atme      'breath'

When the stem appears without being attached by any suffix, a schwa is inserted before the stem-final consonant; the epenthetic schwa never appears after the stem-final consonant. With the ranking in (42), this fact is explained in the tableau in (43). ("|" stands for morphological edge, and "]" prosodical edge.)

(42) **Align-R** » **\*Cod/Nasal**

(43)

/atm/	H-syl	Align-R	*Cod/Nasal	*Ons/Nasal
⇒ .A.tem. ]			*	
.At.mle.]		*!		*
.Atm. ]	*!		*	

Inserting a schwa after the stem-final nasal commits a fatal violation, as the second row shows. The candidate which has a schwa before the nasal wins (the first row); even though the nasal comes to coda position, violation of the constraint **\*Cod/Nasal** is not fatal because it is ranked lower than **Align-R** and **H-syl**. (It is worth noting that the ranking between **H-syl** and

**\*Cod/Nasal** became clear here.<sup>6</sup> Illegal syllabification is more serious than placing a nasal in coda position.)

With the constraint in (40), we can account for the fact observed in the suffixation of *-en* (we assume that the inflectional suffix has a schwa underlyingly, not just *-n*). First, let us observe the case in which the suffix is attached to a stem ending with a vowel.

(44)

/bau/ + /en/	H-syl	Align-R	*Cod/Nasal	*Ons/Nasal	Fill-V	Parse-V
.baun.			*			*!
⇒ .bau.en.			*			
.bau.e.nle.]		*!		*	*	

Inserting a schwa after the suffix violates **Align-R**, and thus the third candidate loses. Both of the two remaining candidates violate **\*Cod/Nasal**, so the determination is carried over to the lower ranked constraints. The first candidate does not parse the underlying schwa, violating **Parse-V**. This violation being fatal, the first candidate loses.

The case in which *-en* is attached to a stem-final nasal is explained in a similar way.

(45)

/atm/ + /en/	H-syl	Align-R	*Cod/Nasal	*Ons/Nasal	Fill-V	Parse-V
.at.mn.	*!		*			*
.a.temn.	*!		*		*	*
⇒ .at.men.			*	*		
.at.mc.nle.]		*!		*	*	

The first candidate, which does not parse the schwa of the suffix in the input, and the second candidate, which has an epenthetic schwa before the stem-final /m/ instead of parsing the suffixal schwa, both violate **H-syl** because the syllables /mn/ and /temn/ are illegal in German, and thus lose. The fourth candidate satisfies **\*Cod/Nasal** by inserting a schwa after the suffix to syllabify the /n/ as the onset, but this candidate violates the more important constraint **Align-R**. Although the third candidate violates **\*Cod/Nasal**, it satisfies **Align-R** and thus wins.

On the other hand, the determination of the optimal form of liquid-ending stems is made in the ranking between **\*Ons/Liquid** and **\*Cod/Liquid**. Recall that in this case the stem-final sequence is /eln/, not /len/.

(46)

/hand/ + /en/	H-syl	Align-R	*Ons/Liquid	*Cod/Liquid	Fill-V	Parse-V
.hand.ln.	*!		*!			*
⇒ .han.deln.				*	*	*
.han.dlen.			*!			

(The candidate which has the epenthetic schwa after the suffix is excluded from consideration, because such a constraint violates the important constraint **Align-R**, as we have seen above.) As for the first candidate, in which the stem-final /l/ is syllabified as the onset and the /n/ of the suffix as the nucleus because of the underparsing of the suffixal schwa, violation of either **\*Ons/Liquid** or **H-syl** is fatal and thus loses (note that we do not have crucial evidence which suggests the ranking between the two constraints). The third candidate also loses, because it violates **\*Ons/Liquid** with the suffix attaching directly to the stem. The second candidate is selected as the optimal form; although this form includes both deletion of the suffixal schwa and insertion of a new schwa before the stem-final liquid, this candidate is better than the two candidates above, satisfying important constraints **\*Ons/Liquid** and **H-syl**.<sup>7</sup>

#### 4.3 Conclusion

We have briefly seen how German schwa is treated in the two analyses. In rule-based analysis, it is necessary to assume three schwa-epenthesis rules; i.e. (29), (32), and (34). Although the rule in (29) is considered to be natural since it has motivation to syllabify unsyllabified segments, two remaining rules are arbitrary, lacking motivation: the rules in (32) and (34) just say a schwa is inserted in such and such positions in such and such cases. On the other hand, OT analysis does not need any arbitrariness. The difference of the place in which a schwa appears arises depending on the preference of the stem-final consonant for the onset or the coda. No special procedure is necessary for the suffix *-en*; the constraints correctly predict the real output. From these facts, we can conclude that OT analysis is more preferable for German schwa, as well as for Final Devoicing.

## 5 Summary

As for the problem that some words do not undergo Final Devoicing, Rubach tried to solve it by assuming a special mechanism of cyclic syllabification in German. His analysis, however, raises several problems as we have seen in section 2.1; that is, (i) arbitrary ordering

of Sonorant Syllabification and Sonorant Desyllabification; (ii) the difference of resyllabification between *Handlung* and *kindisch*; (iii) unmotivated cycle for *Begegnung*; and (iv) wrong prediction for /regn/ + /t/. Moreover, the rule-based analysis includes arbitrariness in analyzing German schwa: when the stem-final segment is a liquid or a vowel, the rule in (32) or (34) applies respectively; otherwise (29) applies.

On the other hand, OT analysis correctly predicts whether Final Devoicing applies to a word, or whether an epenthetic schwa appears and where, without posing any arbitrariness. The constraints assumed here are the following.

- (47) a. **CodaCon, SonLic » Parse-[v]** (= (24))
- b. **H-syl, \*Cod/Nasal » \*Ons/Nasal, Fill-V, Parse-V**  
           **H-syl, \*Ons/Liquid » \*Cod/Liquid, Fill-V, Parse-V** (= (36))
- c. **H-syl, Align-R » \*Cod/Nasal** (cf. (42) and (43))

(47b) and (47c) can be simplified in the following way:

- (48) **Align-R, H-syl » \*Cod/Nasal » \*Ons/Nasal, Fill-V, Parse-V**  
       **Align-R, H-syl, \*Ons/Liquid » \*Cod/Liquid, Fill-V, Parse-V**

These consistent rankings succeed in analyzing Final Devoicing and occurrence of schwas in German properly.

Only a part of the constraint ranking became clear in this paper. This is because we have analyzed only a part of German phonology. By making a more detailed research of this language, or of OT itself, the whole ranking, including constraints not discussed here, will become clear. We will await such future studies.

## NOTES

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<sup>1</sup> The reason why this rule is not stated in the traditional generative way (that is, with an arrow) is that when two schwas are available it depends on the class of the word which schwa deletes. Compare *handeln* 'trade (1st. pl.)', which is assumed in this analysis to be derived from *handel* + *en*, with *handle* 'trade (1st. sg.)', from *handel* + *e*. In the former the schwa after the sonorant deletes, while it is the schwa before the sonorant which is deleted in the latter.

<sup>2</sup> Actually there is a form *Hände* 'hand (pl.)', but in this form the schwa is a suffix.

<sup>3</sup> The constraint in (22) could be decomposed into several constraints. One of them would be as follows:

(i) **Align-Feature:** Align (Stem, R, Feature, R)

This constraint requires that the right edge of the stem coincide with that of a feature. In other words, this constraint prohibits a feature from branching over segments between the stem and the suffix (see McCarthy and Prince (1993) for a detailed discussion on alignment). The structure in (23) is prohibited by this constraint. However, because the aim of this paper is to show that Final Devoicing is best analyzed in OT, (22) is enough for us. We will await future researches for the decomposition of the constraint.

<sup>4</sup> These constraints may be a subgroup of the constraint group **\*P/α**, which prohibits a segment from lying in the peripheral position of the syllable, that is, from being the onset or the coda (cf. Prince and Smolensky (1993)).

<sup>5</sup> Later, the ranking between **H-syl** and **\*Cod/Nasal** becomes clear. Others may also be ranked, but now we do not have evidence to prove their ranking. We should await future researches.

<sup>6</sup> The ranking between **H-syl** and **\*Ons/Liquid** is still unclear. It is not obvious why the candidate *Handle* for the input /handl/ loses: it may be **Align-R** or **\*Ons/Liquid** that determines the choice. (If it is the former, we can conclude that **H-syl**, which is ranked in the same position as **Align-R**, is in the higher position than **\*Ons/Liquid** in the hierarchy.) Moreover, as we see in (46), we cannot determine which violation of the constraints is fatal for the candidate *.hand.ln.*, **H-syl** or **\*Ons/Liquid**.

<sup>7</sup> The word *mal-en* 'paint' syllabifies /l/ as the onset but still the form is optimal; *\*mal-n* never becomes the real output. From the fact that German does not have a word which ends with *-Vln* other than *-eln*, we assume that German has a constraint which prohibits such a sequence, and that this constraint is included in **H-syl**.

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